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GARD FINAL REPORT A1-11 (1713)

June 1980

FEMA Work Unit 1214B

ADEQUACY OF WIND VENTILATION IN UPGRADED SHELTERS

by

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Final Rept.

For

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Washington, D.C. 20472

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INTRODUCTION

The objective of this study was to assess the adequacy of natural ventilation for application to upgraded shelters; i.e., shelters having full earth berms with at least 6 inches of earth overhead. It was realized that the wind induced ventilation air flow rate through a building is a complex function of several geometric and flow variables. Important among these variables are wind speed, wind direction, boundary layer profile of the approaching wind, building geometry, areas and locations of windows and doors, internal obstacles within the building and the nature and proximity of neighboring buildings and obstructions. Data acquisition from experiments of full size buildings was considered expensive and time consuming. The approach taken therefore, was to conduct controlled tests on properly designed scaled model systems. A series of tests were designed to yield a clear understanding of the effects of the important variables individually, and in groups, on the ventilation airflow rates. The building geometry was kept relatively simple and internal flow resistances were excluded. Natural ventilation due to thermal effects were also ignored since the shelters were considered to be one story high.

SCALED MODEL TESTS

A low speed wind tunnel was designed and constructed especially to suit air flow studies involving simulation of wind velocity profiles and the measurement and visualization of airflow through buildings. A photograph and a schematic of the wind tunnel are shown in Figures 1 and 2. Photographic measurement techniques were developed which utilized flow tracing of neutrally buoyant bubbles through the building models. Figure 3 shows a typical test setup.

EXPERIMENTAL RESULTS

The scaled model flow rates and full scale flow rates as a function of wind speed and wind approach angle for the three shelter configurations studied are shown in Figure 4. In general, the following was observed:

1) At any given relative wind angle the ventilation flow rate through all three models varies linearly with wind speed.
2) For models I and II, the ventilation flow rate does not vary significantly for relative wind angles between 0^{o} and 45^{o}, while for model III

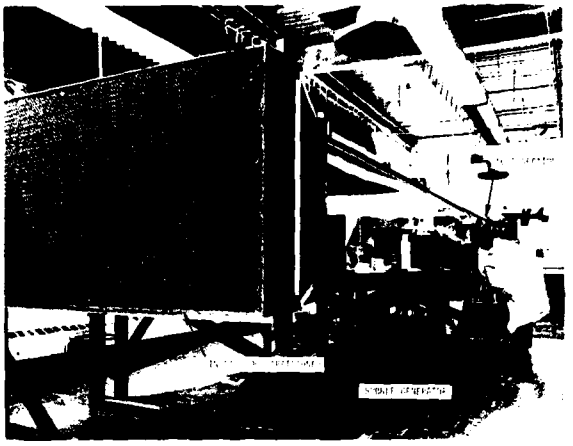


Figure 1 LOW SPEED WIND TUNNEL

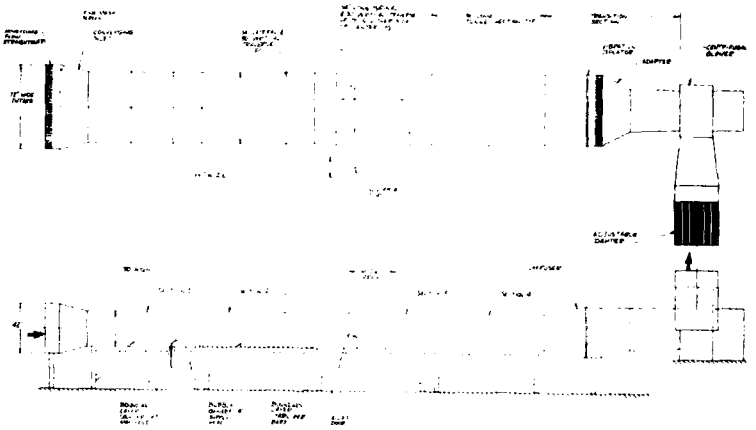


Figure 2 SCHEMATIC OF WIND TUNNEL

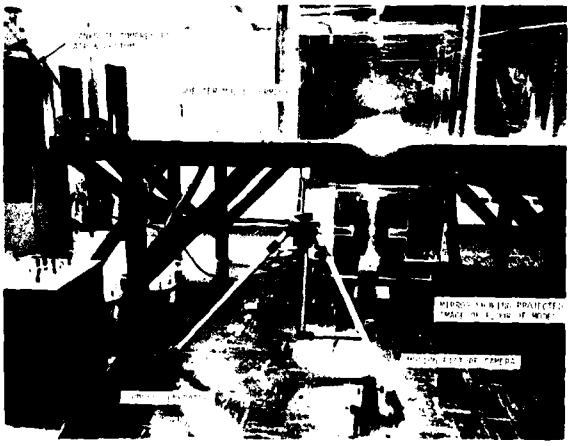
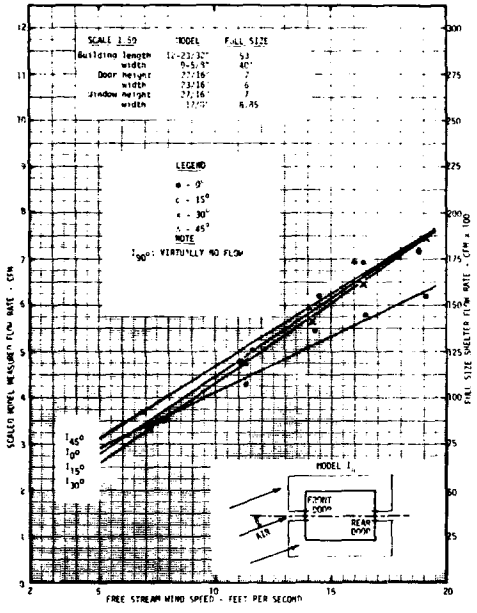
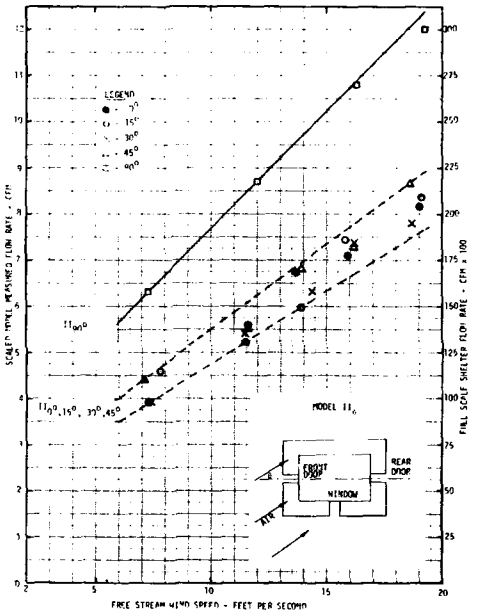


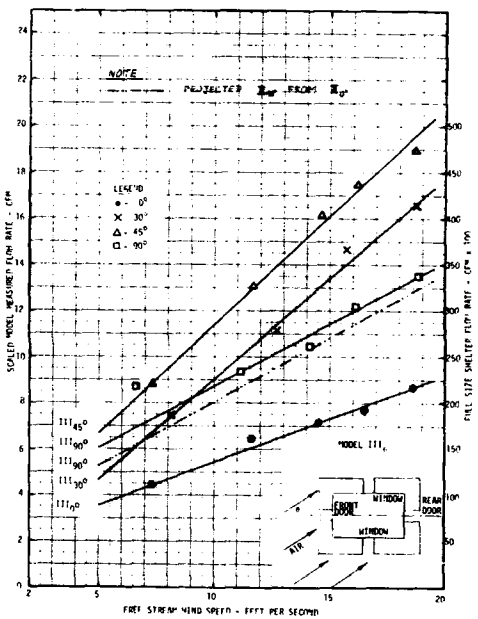
Figure 3 TYPICAL TEST SET-UP



MODEL I



MODEL II



MODEL III

Figure 4 VENTILATION THROUGHPUT CFM vs V_∞ FOR MODELS I, II AND III

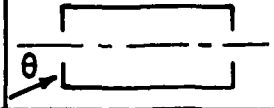
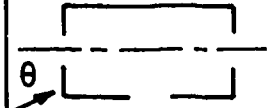
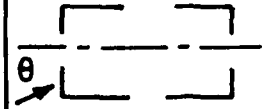
considerably greater flows were experienced at non-zero angles than at 0^{o}.

3) Increasing the opening area on the windward side alone or the leeward side alone does not augment the throughput rate very much.

CONCLUSIONS

For a shelter occupant density of 10 sq. ft. per person, the results as summarized below indicate that sizeable ventilation rates are achieveable at low wind speeds. Based upon data reported by FEMA* these ventilation rates would be adequate to meet the 82^{o}F effective temperature and 90% adequacy criteria for all but the southeast portion of the U.S. Further research is required however, to determine the effects of internal flow resistance provided by partition walls and occupants, air stratification, areas and locations of openings, etc., before these results can be accepted with confidence.

ESTIMATED VENTILATION FLOWS RATES ACHIEVABLE WITH NATURAL VENTILATION BASED ON SCALED MODEL TESTS FOR WIND SPEEDS IN EXCESS OF 5 mph AND OCCUPANT DENSITY OF 10 SQ. FT. PER PERSON

SHELTER	FLOOR AREA (SQ.FT)	OPENING CONFIGURATION	TOTAL OPENING AREA (SQ.FT)	VENTILATION RATE (CFM/OCC)		
				0^{o}	45^{o}	90^{o}
I	2120		84	41	44	0
II	2120		146	46	52	75
III	2120		208	50	103	102

* FEMA indicates that 7.5 to 40 CFM per person is adequate to maintain 82^{o}F effective temperature and 90% adequacy (Ref: ASHRAE Applications Handbook, 1978, Chapter 12, Figure 13)

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TO Distribution DATE August 19, 1980

FROM R. Henninger

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GARD Report A1-11
FEMA Work Unit 1214B

It has been brought to my attention that some copies of the subject report distributed to you recently did not contain a copy of the "Detachable Summary". Accordingly a copy(s) are enclosed for your files. Please excuse this inconvenience.

Thank you,

R. H. Henninger

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